Attachment A1 - Effects of Releases of Sediment During Dredging

Modeling analyses were conducted to evaluate the effect of sediment and contaminants released during dredging to support the selection of monitoring locations that will provide data for comparison to the Resuspension Performance Standard. These analyses were performed with the models that had been used in the evaluation of alternatives to support the development of the ROD. Linked modeling components used in the evaluation of alternatives leading up to the ROD included hydrodynamic, sediment transport, organic carbon production and transport, and contaminant fate and transport models. Alternatives evaluated in support of the ROD included a No-Action alternative and three alternatives with active remediation, from which the alternative "Capping with Dredging for Flooding and Navigation" was selected and incorporated in the ROD. Details of these remedial alternatives (e.g. dredging and capping sequence and schedule, production rates, etc.) are presented in Appendix V (Responsiveness Summary) of the ROD (EPA, March 2016).

The simulations performed for the active remedial alternatives involved running the model from 2013 (end of the calibration period) to July 2020 when construction was assumed to begin, then through the period of construction (December 2025 for the selected remedy) and for a period of 30 years after completion of construction. The hydrographs and tidal boundary conditions used for the alternatives were developed by repeating the model inputs (boundary inflows and tides) for the period of October 1995 – October 2010 (water years 1996-2010) in 15-year cycles and appending them to the historical water year 1995 – 2013 inputs to generate one continuous simulation for the period of water years 1996 through 2064. The No-Action alternative is identical to the active remedial alternatives up to July 2020, and uses the same hydrographs and tidal boundary conditions as the active alternatives, but does not include any remediation during the period of construction for the three active remedial alternatives. Results from the No-Action alternative are used for comparison to results from the Selected Remedy, as described below.

The analyses described in this Attachment were performed to evaluate the effect of sediment and contaminants released during dredging, with the objective of assessing what might be observed in results of monitoring upstream and downstream of dredging operations. These analyses will provide a basis for assessing whether conditions during the actual construction are consistent with expected releases during dredging and identify time periods when corrective actions may be needed to bring construction performance back into the range of acceptable conditions.

As sediment is released to the water column during dredging, carbon and contaminants associated with the sediment are also released. Model simulations of the remedial alternatives for the Lower 8-miles of the LPR assumed 3 percent of the mass of sediment, organic carbon and contaminants removed with dredging is released to the water column, with 1.5% released in the bottom layer and 1.5% released in the surface layer of the water column. In addition to comparing results of the Selected Remedy and No-Action simulations to assess the fate of sediment and contaminants released during dredging, simulations were also run with additional variables added to the code to numerically tag sediment and contaminants released during dredging. This was accomplished by creating a parallel set of variables to track only the sediment or contaminants released during dredging, while sediment and contaminants from all other sources (i.e. boundary inputs and resuspension of native sediment) were simulated in the standard variable used to calculate concentrations of each size class (for sediment) and contaminant in every grid cell in the water column and bed each time step through the simulation. Total sediment and contaminant concentrations are obtained by adding the concentrations in the original and new tagging variables. The results of this assessment are intended to inform monitoring requirements at "near-field" and "far-field" locations.

The model simulation of the remedy includes dredging in 235 mode grid cells, with a sequence and scheduled developed and refined as part of the preparation of the Proposed Plan and the subsequent Responsiveness Summary. Results for representative locations, spaced at approximately two mile intervals throughout the Lower 8.3 miles, are presented as temporal plots of water column surface layer suspended sediment (SSC). The time periods presented for a given grid cell coincide with the time when dredging is simulated at that location (see Figure 1 for a map summarizing the dredging schedule). On each page, the top panel shows the flow at Dundee Dam on the left y-axis (shaded area) and the water surface elevation in the cell being dredged on the right axis (green line). The hydrographs and tidal boundary conditions used for the alternatives were constructed by repeating the model forcing for the period of October 1995 – October 2010 (water years 1996-2010) in 15-year cycles. The remaining three panels from top to bottom present computed SSC (or fraction of SSC from dredging releases) in three adjacent model grid cells from upstream to downstream, respectively, with the river-mile of the grid cell indicated on the right side of each panel. It is noted that in some cases, dredging may proceed to a grid cell adjacent to one of the three cells shown for a specific location. The schedule of dredging begins concurrently on July 1, 2020, at two locations (RM 8.3 and RM 2.6) and progresses in the downstream direction from each starting point, ending in December 2025 (Figure 1). It is assumed that at each dredging location, 3% of the dredged sediments are resuspended and released into the water column. A portion of this material is then transported across the upstream and downstream boundaries of the study area (RM 8.3 and RM 0, respectively).

River Mile 8.1

Figure 2 presents water column surface layer SSC for a 28-day period in August 2020 from the no action (blue line) and selected remedy (red line) model simulations. From top to bottom, the three SSC time series panels present results for contiguous grid cells at RM 8.2, 8.1, and 8.0, respectively, with shading in each panel to indicate the time when dredging is simulated in that grid cell. Changes in the magnitude of SSC in the period between August 8 and August 11, 2020 versus August 16 to August 20, 2020 are primarily due to the transition from spring to neap tide conditions, as indicated by the water surface elevations shown as the green line in the top panel.

Although differences between SSC from the no-action and selected remedy are generally small, averaging less than 3 mg/l during the period of dredging, solids released during dredging do contribute to the simulated SSC in the Selected Remedy simulation. Results from the Selected Remedy simulation in which solids released during dredging are computed in a variable separate from solids from all other sources are shown on Figure 3 for a 7 day period that falls within the 28 day period shown on Figure 2. The 7-day time period is shown on Figure 3 to allow the portion of SSC originating from dredging releases (blue shading on SSC time series) to be seen more clearly. The fraction of SSC originating from dredging releases (purple line; right y-axis) increases from approximately 30 percent to more than 50 percent (with peaks near 80 %) as the magnitude of the total SSC decreases with decreasing tidal amplitude during this period. Dredging was simulated in the grid cells to the west of the three shown on Figures 2 and 3 in the preceding month, so some of the solids tracked as originating from dredging releases were released during the prior month and not flushed out of the area during this low flow period.

The SSC results shown on Figures 2 and 3 are from the surface layer of the water column. Figure 4 shows results for the bottom layer of the water column for the same time period shown on Figure 3. SSC in the bottom layer follows the same general pattern, with slightly higher concentrations and slightly lower percentages originating from dredging, compared to the surface layer. Percentages of SSC originating from dredging in the surface and bottom layers is shown on Figure 5 for the same 28-day time period shown on Figure 2. The higher percentage of SSC originating from dredging in the surface layer is due to the same mass of solids released from dredging in the surface and bottom layers (1.5 % of solids mass dredged released to each layer) added to a generally lower SSC in the surface layer, given the typical vertical solids gradient.

As an initial screening of what might be observed if SSC sampling was carried out upstream and downstream of the dredging operation, SSC in the grid cell upstream of the dredging location were subtracted from the SSC in the grid cell downstream (matched in time at hourly intervals). Although not presented graphically, statistical evaluations of the differences indicate that when dredging is simulated at RM 8.1, surface layer concentration differences average less than 1 mg/l; downstream concentrations are higher than upstream by 3 mg/l or more 10 percent of the time and upstream concentrations are higher than downstream by approximately 2 mg/l or more 10 percent of the time. Bottom layer SSC differences between grid cells downstream and upstream of the dredging operation average less than 1 mg/l. Bottom layer downstream concentrations are higher than upstream by approximately 5 mg/l or more 10 percent of the time and upstream concentrations are higher than downstream by approximately 5 mg/l or more 10 percent of the time. This suggests that monitoring of SSC (or a SSC surrogate such as turbidity) would be useful for identifying substantial deviations from expected conditions, but factors responsible for variability in SSC would likely overwhelm these calculated concentration differences.

River Mile 6.3

Dredging near RM 6.3 (Figure 6) is simulated near the beginning of year 2022, during a period when river flows are closer to the annual average and tidal conditions are predominantly spring tides. Surface layer SSC during the period of dredging averages approximately 18 mg/l in the Selected Remedy simulation, which is roughly 3 mg/l higher than the No-action Alternative. In the week before dredging in the grid cell at RM 6.3, which has predominately neap tide conditions, SSC in the surface layer averaged less than 10 mg/l in both the Selected Remedy and No-action simulations. During the week after dredging, which also has predominately neap tide conditions but lower flow, SSC in the surface layer averaged around 4 mg/l.

Figures 7 and 8 show the portion of the surface and bottom layer SSC originating from dredging releases during a 7-day period when dredging is simulated. The SSC from dredging releases represents a smaller fraction of the total SSC, at this location, as compared to the results presented previously for RM 8.1, due to the greater magnitude of SSC originating from all sources (riverine and tidal boundaries and natural resuspension) other than dredging releases. At this time, the mass loading of solids from dredging releases represents an increment to a larger base concentration, resulting in an average of approximately 20 percent (see Figure 8) of the total SSC originating from dredging releases. It is noted that SSC monitoring alone will not be able to distinguish solids originating from dredging releases versus other sources.

A statistical evaluation of the differences in hourly surface layer SSC when dredging is simulated at RM 6.3, indicates that concentration differences average less than 1 mg/l; downstream concentrations are higher than upstream by 7 mg/l or more 10 percent of the time, and upstream concentrations are higher than downstream by approximately 5 mg/l or more 10 percent of the time. Bottom layer SSC differences between grid cells downstream and upstream of the dredging operation average less than 4 mg/l. Bottom layer downstream concentrations are higher than upstream by approximately 13 mg/l or more 20 percent of the time and by 33 mg/l 10 percent of the time. Upstream concentrations are higher than downstream by approximately 25 mg/l or more 10 percent of the time, although the larger differences are also noted to a significant degree in the No Action simulation.

River Mile 4.0

Dredging is simulated at RM 4 in November 2023 and surface layer SSC time series results from the Selected Remedy and No-action simulations are shown on Figure 10 for this period. Flow conditions at this point in the simulation are within a couple of hundred cfs of the annual average, although an increase of approximately 1000 cfs occurs near the end of the dredging period for the grid cell at RM 4.0. An increase in the SSC for both simulations is noted on November 16 in response to an increase in river flow. During the period of dredging, SSC concentrations averaged near 10 mg/l in both simulations, with the difference between SSC computed in the Selected Remedy and No-action simulations of near 1 mg/l in the surface and bottom layers.

Results from the Selected Remedy simulation in which solids released during dredging are computed in a state variable separate from solids from all other sources are shown on Figure 11 and 12 (surface and bottom water column layers, respectively) for the 7-day period of dredging at RM 4.0. Even though differences between SSC in the Selected Remedy and No-action simulations are near 1 mg/l, results shown on Figures 11 and 12 indicate that solids released during dredging are often as much as 5 mg/l in the surface layer and 10 mg/l in the bottom layer. Solids released during dredging account for approximately one third of the SSC, on average in both the surface and bottom layers during the week of dredging (11/11 – 11/18/2023), but considerably less in the grid cells immediately upstream and downstream of the cell where dredging is simulated (see also Figure 13 for a 28-day period).

A statistical evaluation of the differences in hourly surface layer SSC when dredging is simulated at RM 4.0, indicates that concentration differences average less than 1 mg/l; downstream concentrations are higher than upstream by 2 mg/l or more 10 percent of the time, and upstream concentrations are higher than downstream by approximately 2 mg/l or more 10 percent of the time. Bottom layer SSC differences between grid cells downstream and upstream of the dredging operation average less than 4 mg/l. Bottom layer downstream concentrations are higher than upstream by approximately 7 mg/l or more 10 percent of the time. Upstream concentrations are higher than downstream by approximately 8 mg/l or more 10 percent of the time. These differences would be expected to change if dredging were simulated during different tidal or river flow conditions.

River Mile 2.0

Dredging is simulated as two concurrent operations beginning on July 1, 2020, at two locations (RM 8.3 and RM 2.6) and progresses in the downstream direction from each starting point. Therefore, the results shown on Figure 14 for grid cells near RM 2 represent a time approximately six weeks after dredging commenced roughly one half mile upstream of those locations. River flows at the start of dredging at RM 2.0 are low - less than 200 cfs until the last day of dredging, when flows rise by several hundred cfs, but don't reach the annual average flow of over 1100 cfs. In the grid cell where dredging is active, the time series of surface layer SSC (Figure 14) shows differences in concentrations of almost 10 mg/l, on average, between the Selected Remedy and No Action simulations and little difference in adjacent grid cells.

Solids originating from dredging releases (Figure 15 and 16) show an interesting pattern in the grid cells near RM 2.0. In the grid cell being dredged, the solids from dredging releases represent the vast majority of the total SSC in the surface layer (Figure 15) and a sizable fraction of the total SSC in the cell upstream of the dredging location during flood tide, which is mirrored in the downstream grid cell during ebb tide. When dredging moves to the next downstream grid cell, there is an abrupt change in the total SSC concentration and fraction of SSC originating from dredging releases. In the bottom layer of the water column (Figure 16), the pattern of dredging release effects upstream and downstream of the dredging operation on flood and ebb tides is still evident, although not as dramatic as in the surface layer (Figure 15). The abrupt response to the change in location of the dredging operation is just as clear in the bottom layer as in the surface layer. Over a 28-day period (Figure 17) in grid cells near RM 2.0 the percentage of the total SSC that originated from solids released during dredging varies widely with the tides, with the highest percentages in the surface layer when dredging is occurring in a given grid cell or an adjacent cell. The lowest variability occurs in the grid cell where dredging is active.

Repeating the statistical evaluation of the differences in hourly surface layer SSC when dredging is simulated for RM 2.0, indicates that concentration differences average less than 1 mg/l; downstream concentrations are higher than upstream by 6 mg/l or more 10 percent of the time, and upstream concentrations are higher than downstream by approximately 7 mg/l or more 10 percent of the time. Bottom layer SSC differences between grid cells downstream and upstream of the dredging operation average less than 2 mg/l. Bottom layer downstream concentrations are higher than upstream by approximately 10 mg/l or more 10 percent of the time. Upstream concentrations are higher than downstream by approximately 16 mg/l or more 10 percent of the time.

River Mile 0.2

Dredging is simulated at RM 0.2 during a period of low flow with a short transient in flows ranging from approximately a low of 100 cfs to a high of 500 cfs. Patterns in the comparison of SSC from the Selected Remedy and No Action simulations near RM 0.2 (Figure 18) are very similar to those at RM 2.0 (Figure 14), where differences during the period of dredging average approximately 5 mg/l, but even smaller differences are seen in grid cells upstream and downstream of the cell where dredging is simulated. Similar patterns are also noted in the time series of solids originating from releases during dredging in the surface and bottom layers of the water column (Figures 19 and 20, respectively). The pattern of solids from dredging releases in the cell upstream of the dredging operation during flood tide and downstream during ebb tide discussed for RM 2.0 results is also seen in the RM 0.2 results. The temporal patterns and fluctuations of the percentage of solids from dredging releases over a 28-day period at RM 0.2 (Figure 21) are also similar to RM 2.0.

Comparing SSC in grid cells upstream and downstream of the dredging operation at RM 0.2 shows surface layer concentrations differences that average less than 1 mg/l and reach 5 mg/l less than 10 percent of the time. Similarly, differences in bottom layer concentrations upstream and downstream of the dredging average less than 2 mg/l and reach 5 to 10 mg/l less than 10 percent of the time.

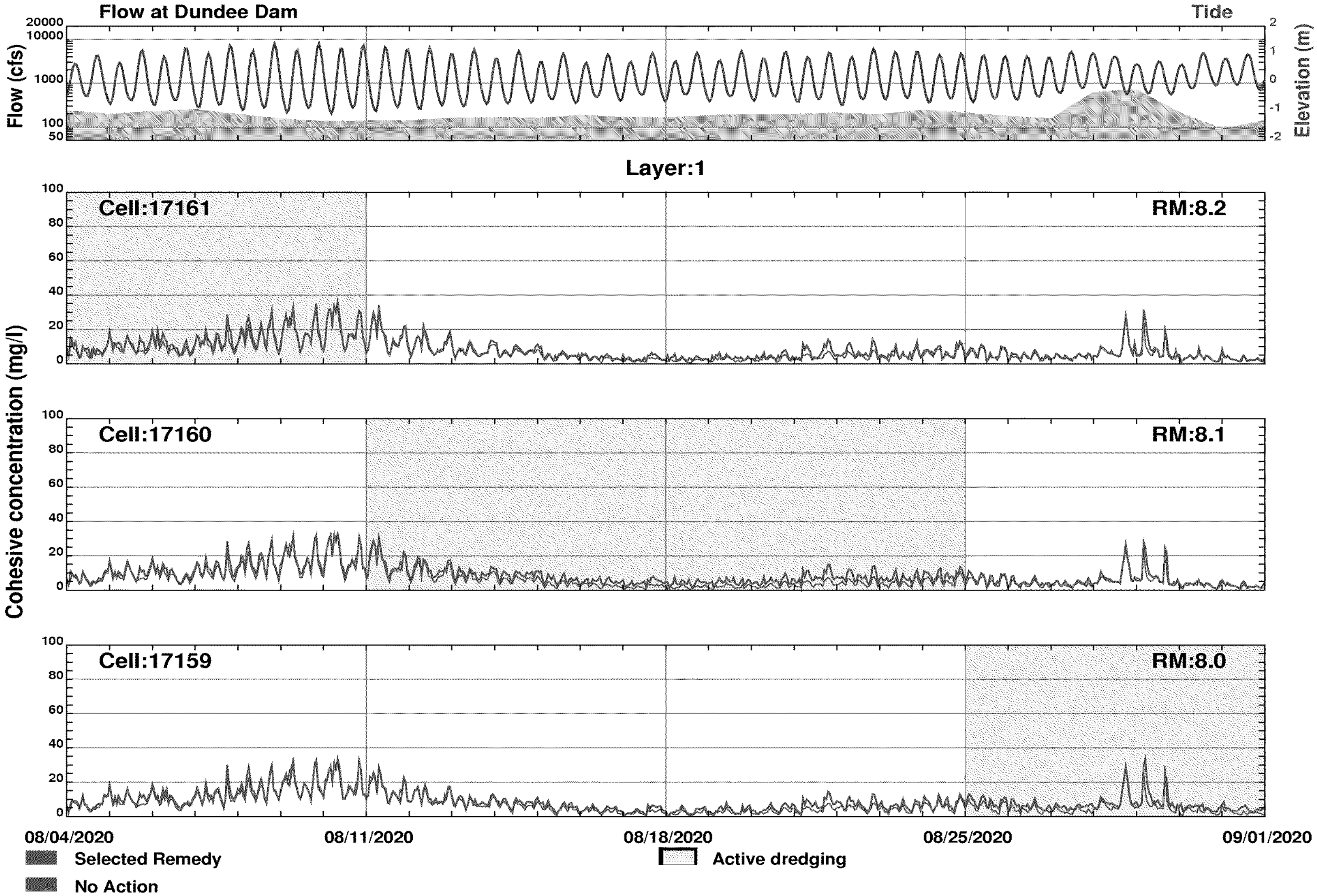
Conclusions

Comparisons of model simulation results for the Selected Remedy and No Action Alternative, and analysis of results from a new simulation (with an additional solids variable to track the movement of solids introduced into the water column during dredging) provide information to inform development of monitoring options that will be part of the engineering performance standards.

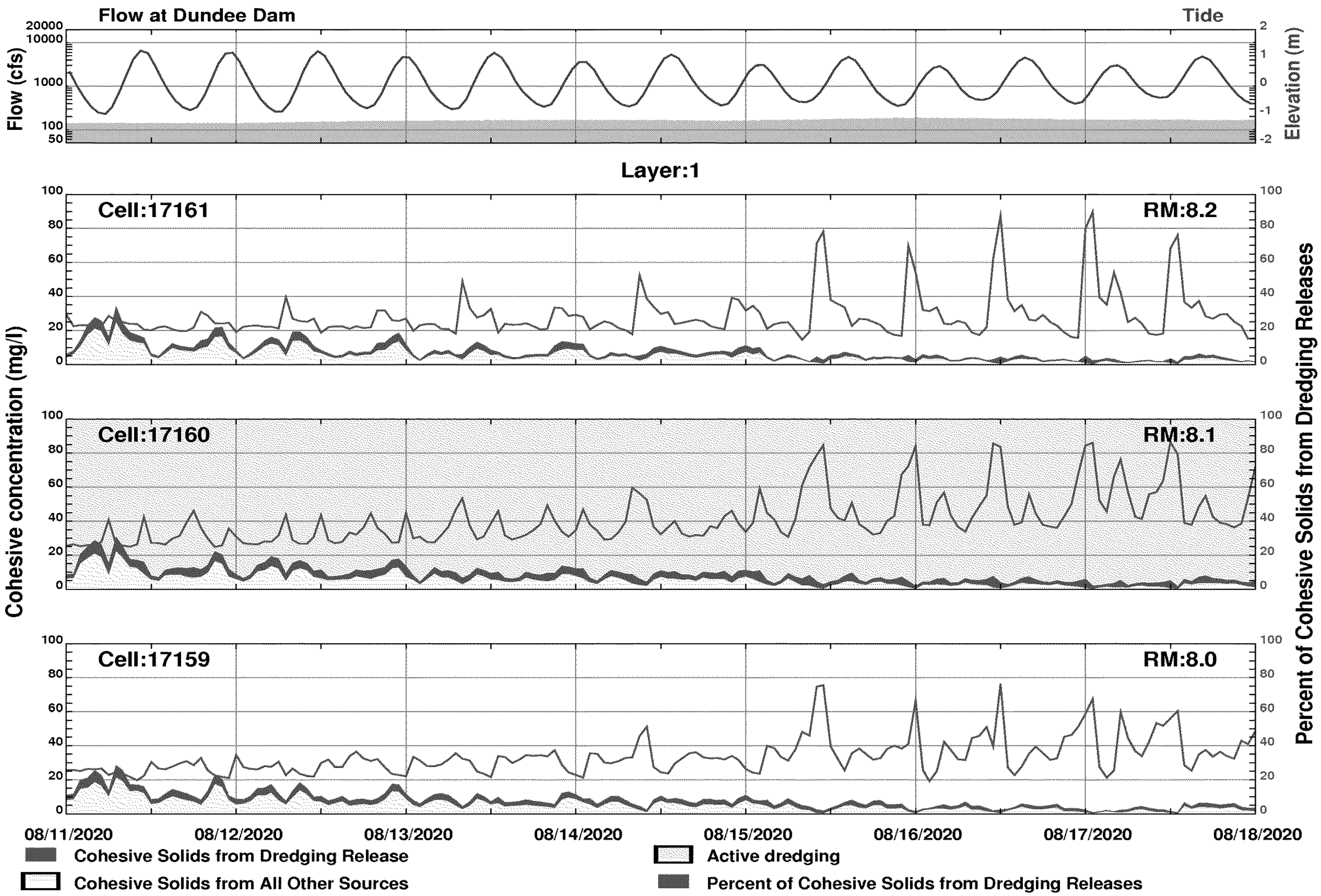
- Suspended sediment measurements (or surrogates such as turbidity or acoustic backscatter) may be useful for detecting substantial excursions from expected conditions, but should not be expected to detect smaller deviations (e.g. a factor of two or three) from assumed solids release rates associated with dredging operations, because the increase in SSC related to releases during dredging averages a few mg/l while the typical intra-tidal variation in SSC is often 30 to 50 mg/l or more.

- Near-field spatial and/or temporal changes in SSC associated with solids releases during dredging vary with location within the river, dredging sequence, and in response to river flow and tidal conditions during the period of construction, which will need to be factored into the performance standards.
- Use of an additional variable to track solids released during dredging provides insight beyond the simple comparison of results from simulations with and without dredging. Results from the release-tracking simulations quantify the degree to which solids originating from releases during dredging replace native sediment in the overall sediment transport process (i.e. solids released during dredging represent concentrations greater than the difference between results from simulations with and without dredging). This leads to the conclusion that monitoring solids (or surrogates) will need to be supplemented with chemical measurements to evaluate compliance with acceptable construction performance.
- Results from contaminant tracking simulations discussed in the proceeding sections of this document will provide additional guidance for the development of engineering performance standards for resuspension.

Dredging Schedule for Selected Remedy	Figure 1
Lower 8.3 Miles of the Lower Passaic River	2016



Comparison of suspended cohesive solids concentrations from Selected Remedy and No Action near RM 8.1 surface layer (Assumption: resuspension loss is 3%of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 2 2016

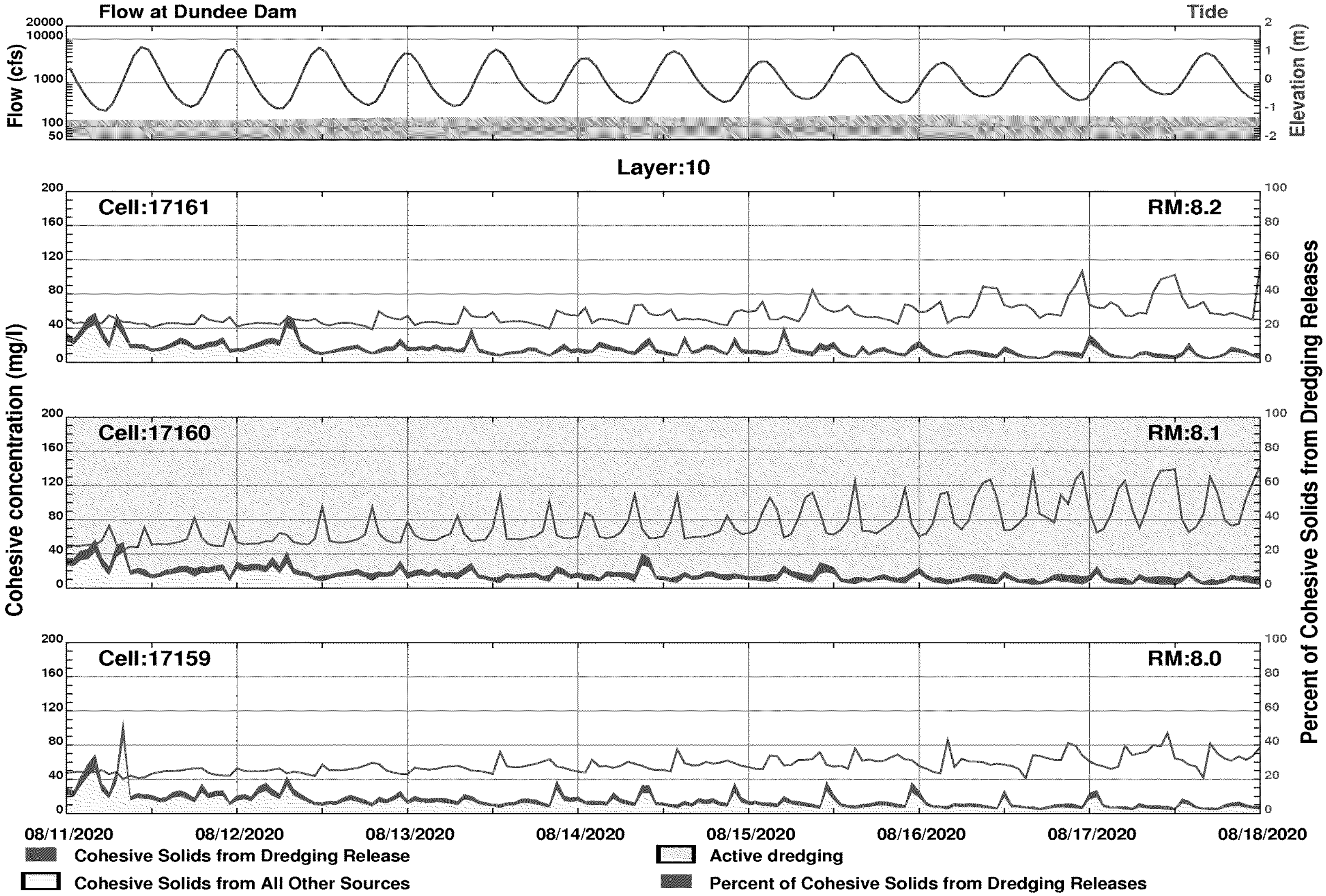


Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 8.1 surface layer (Assumption: resuspension loss is 3% of dredged mass)

Lower 8.3 Miles of the Lower Passaic River

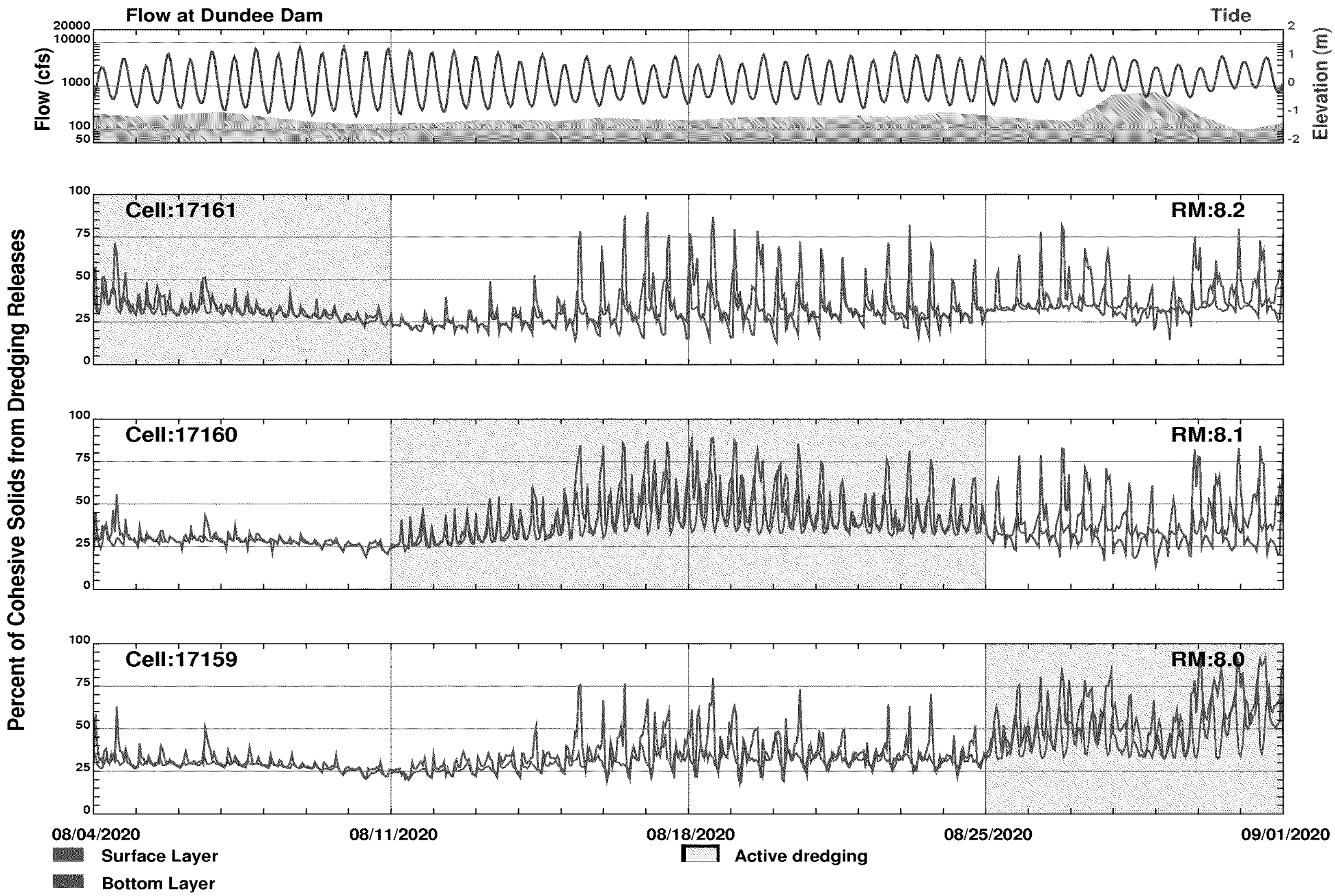
Figure 3

2016

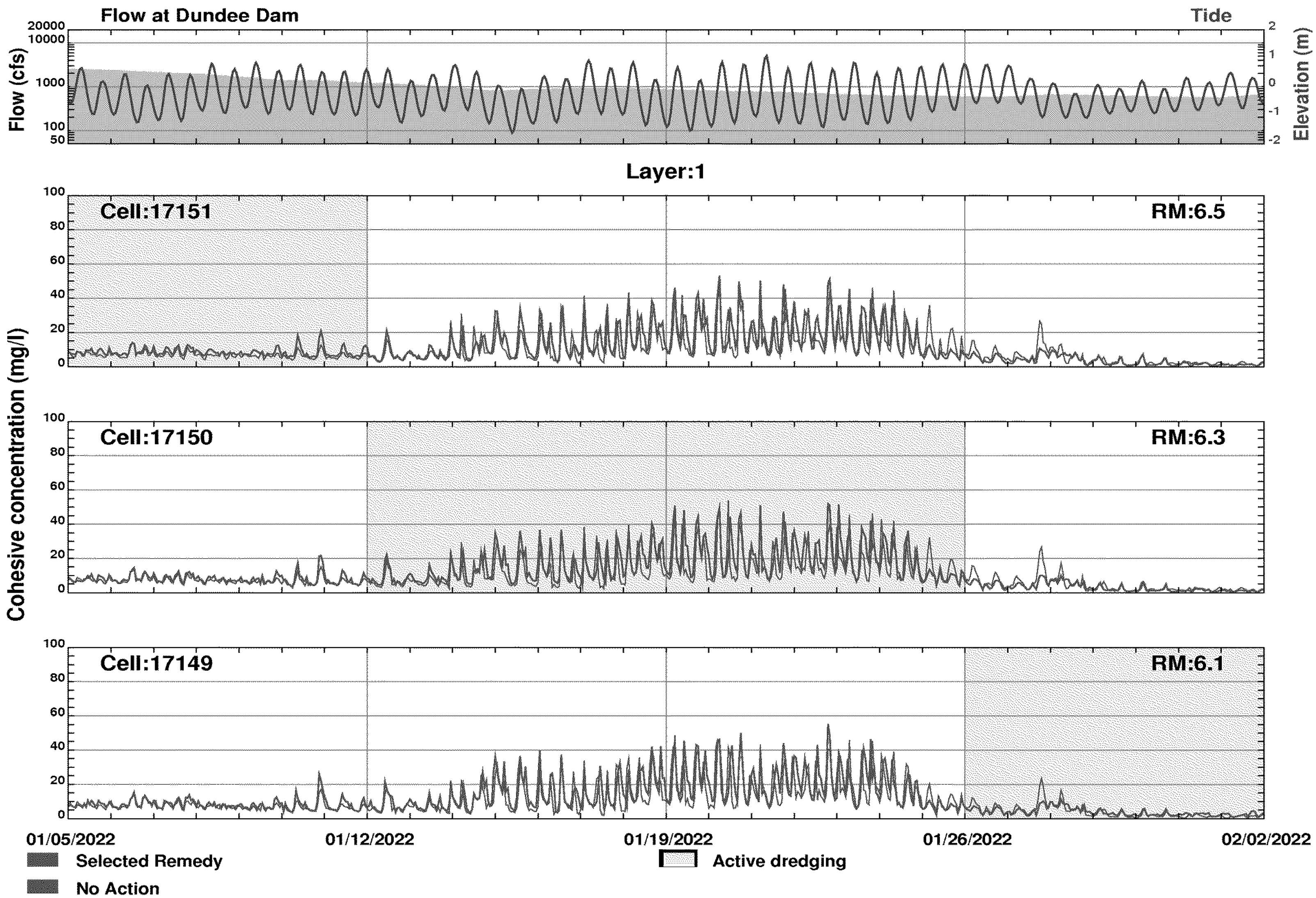


Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 8.1 bottom layer (Assumption: resuspension loss is 3% of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 4 2016

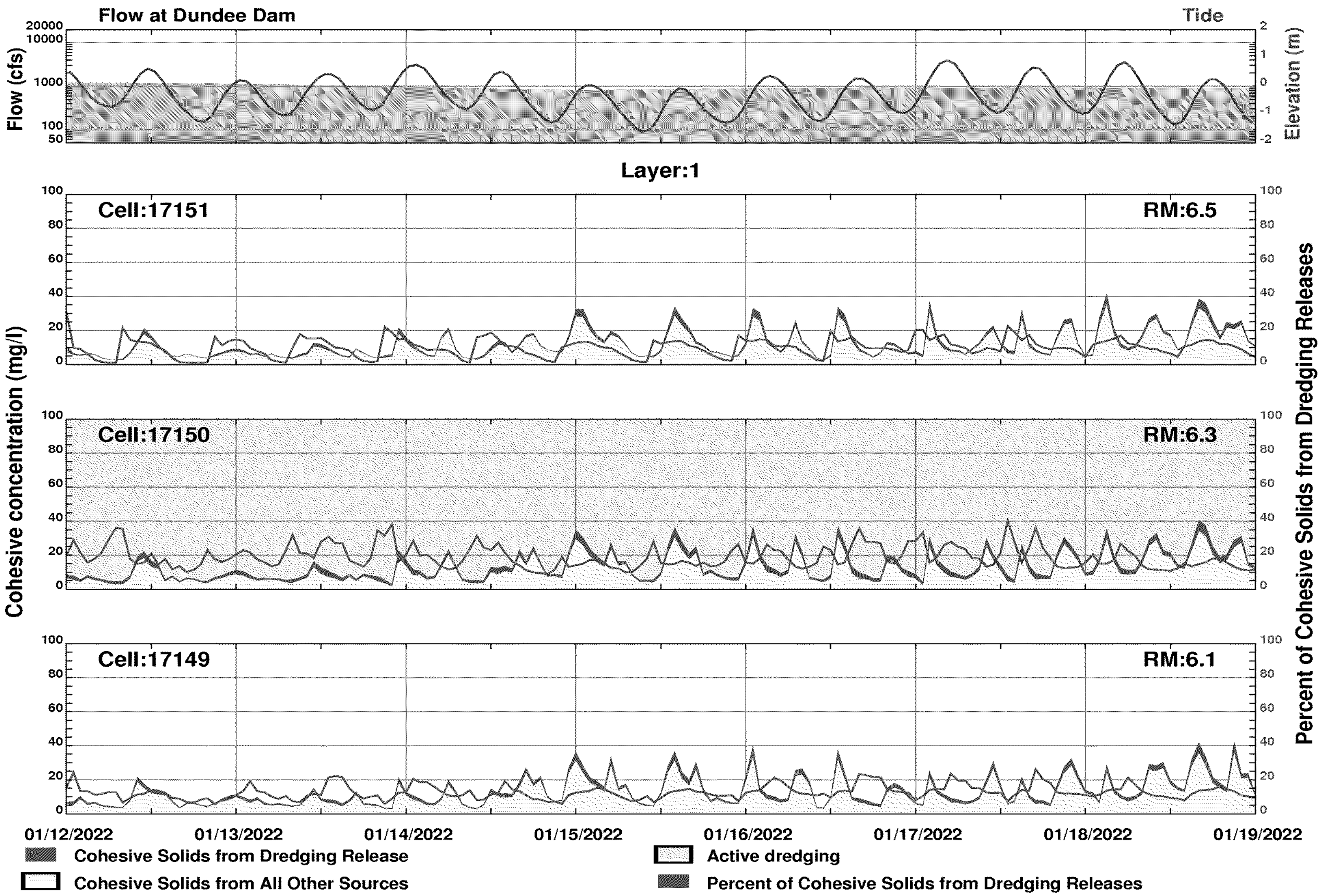
DRAFT shared with Glenn Springs 12/7/16



Percentage of suspended cohesive solids from dredging releases near RM 8.1 (Assumption: resuspension loss is 3% of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 5 2016



Comparison of suspended cohesive solids concentrations from Selected Remedy and No Action near RM 6.3 surface layer (Assumption: resuspension loss is 3%of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 6 2016

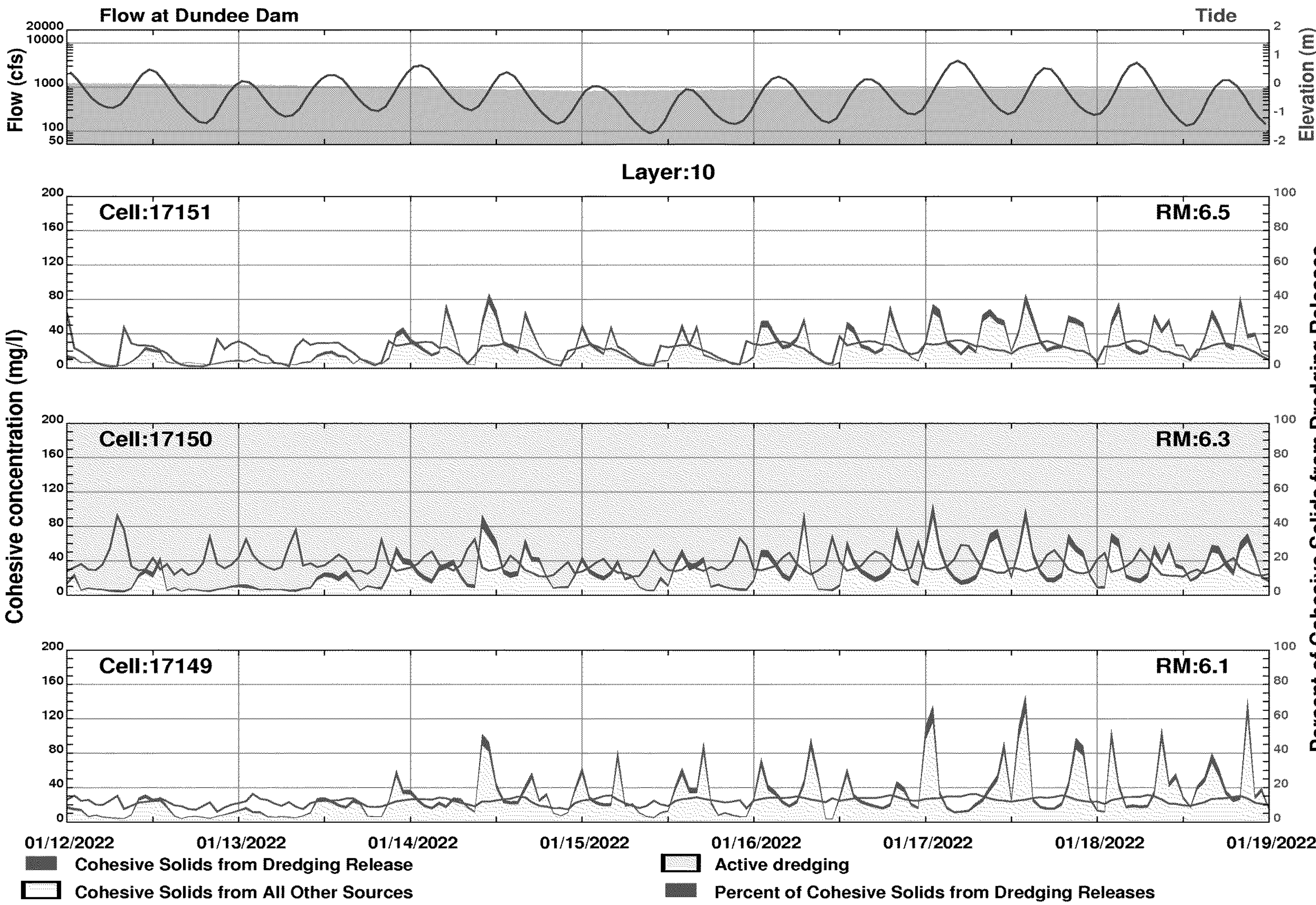


Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 6.3 surface layer (Assumption: resuspension loss is 3% of dredged mass)

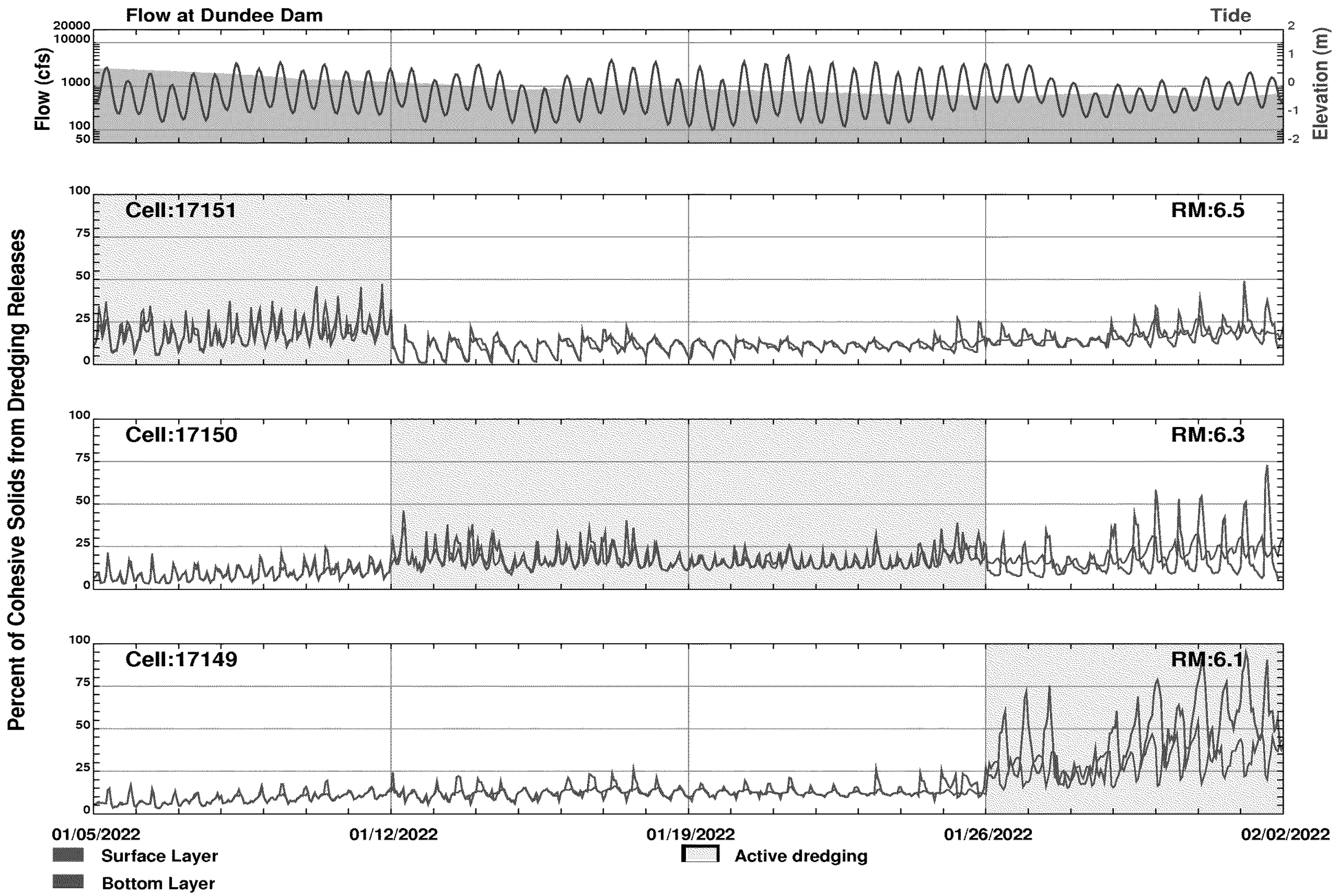
Lower 8.3 Miles of the Lower Passaic River

Figure 7

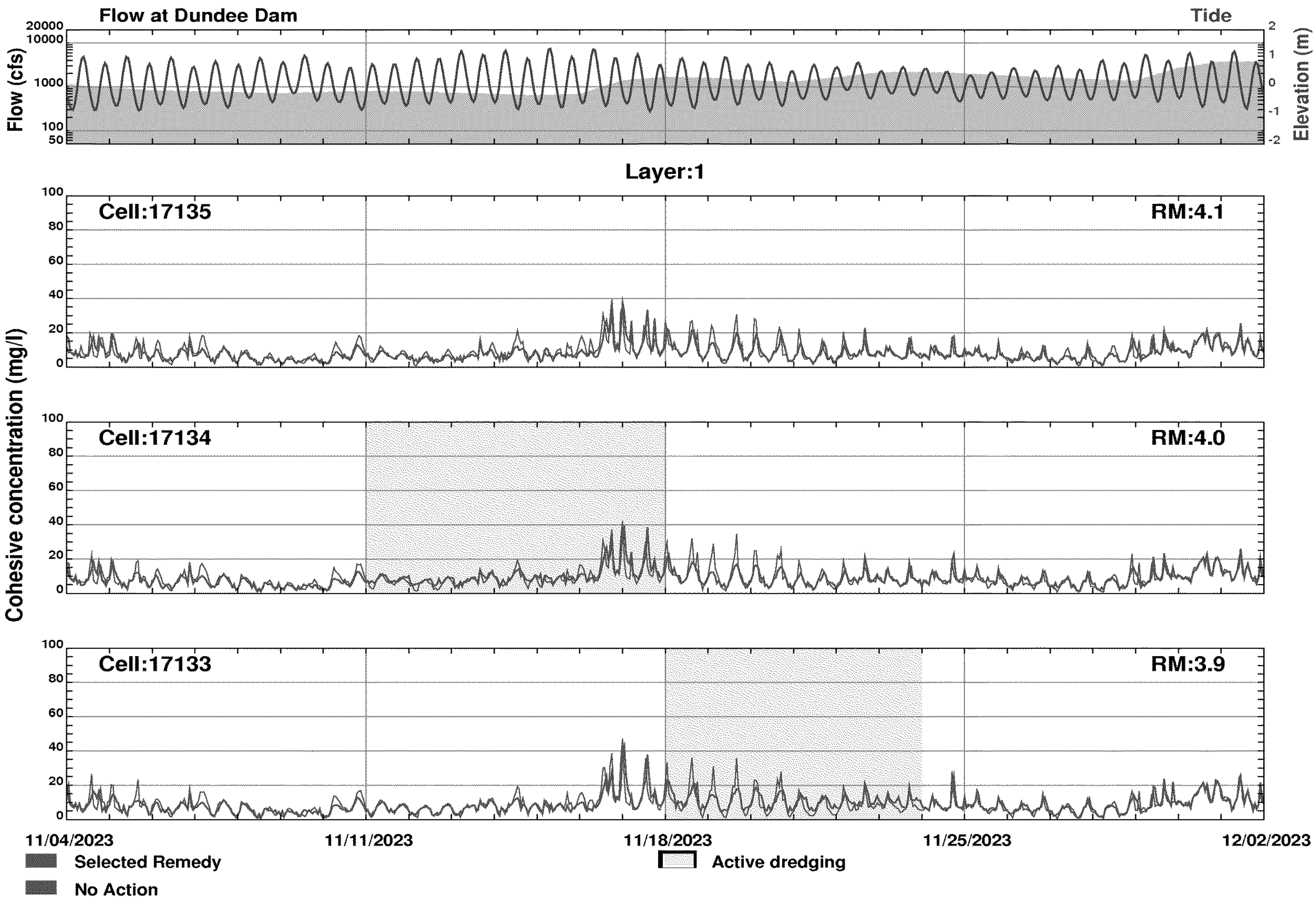
2016



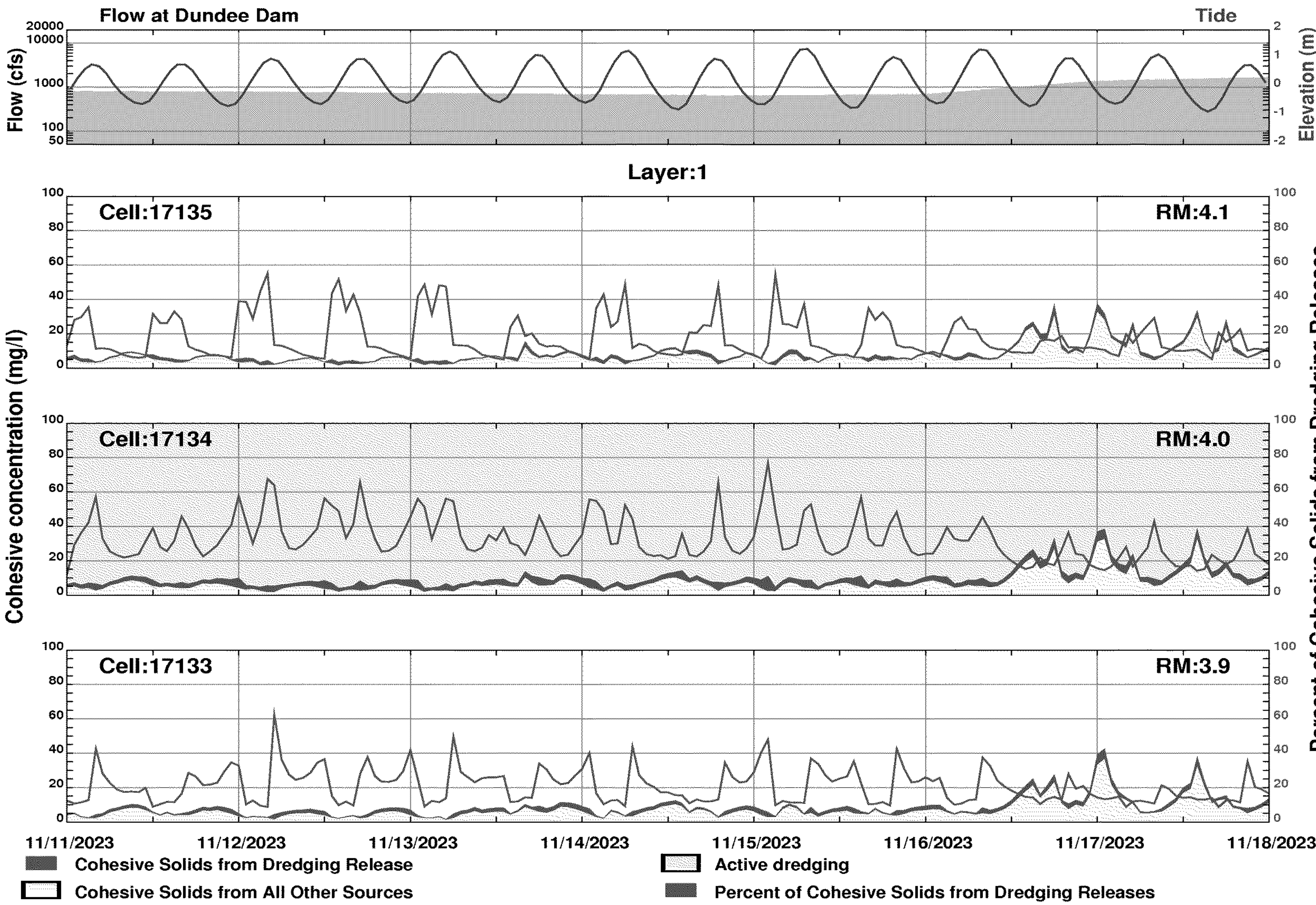
Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 6.3 bottom layer (Assumption: resuspension loss is 3% of dredged mass)	Figure 8
Lower 8.3 Miles of the Lower Passaic River	2016



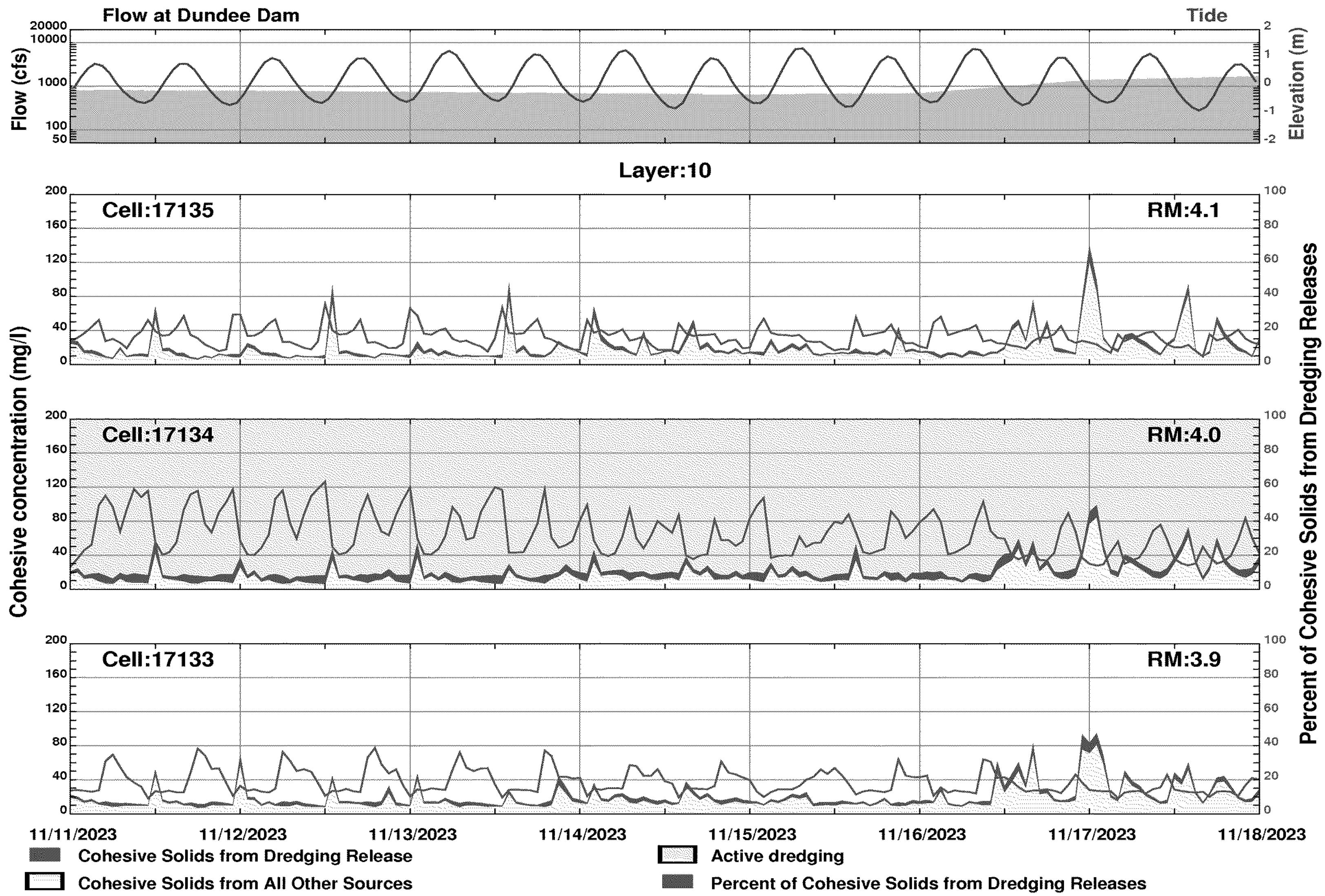
Percentage of suspended cohesive solids from dredging releases near RM 6.3 (Assumption: resuspension loss is 3% of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 9 2016



Comparison of suspended cohesive solids concentrations from Selected Remedy and No Action near RM 4.0 surface layer (Assumption: resuspension loss is 3%of dredged mass)	Figure 10
Lower 8.3 Miles of the Lower Passaic River	2016



Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 4.0 surface layer (Assumption: resuspension loss is 3% of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 11 2016

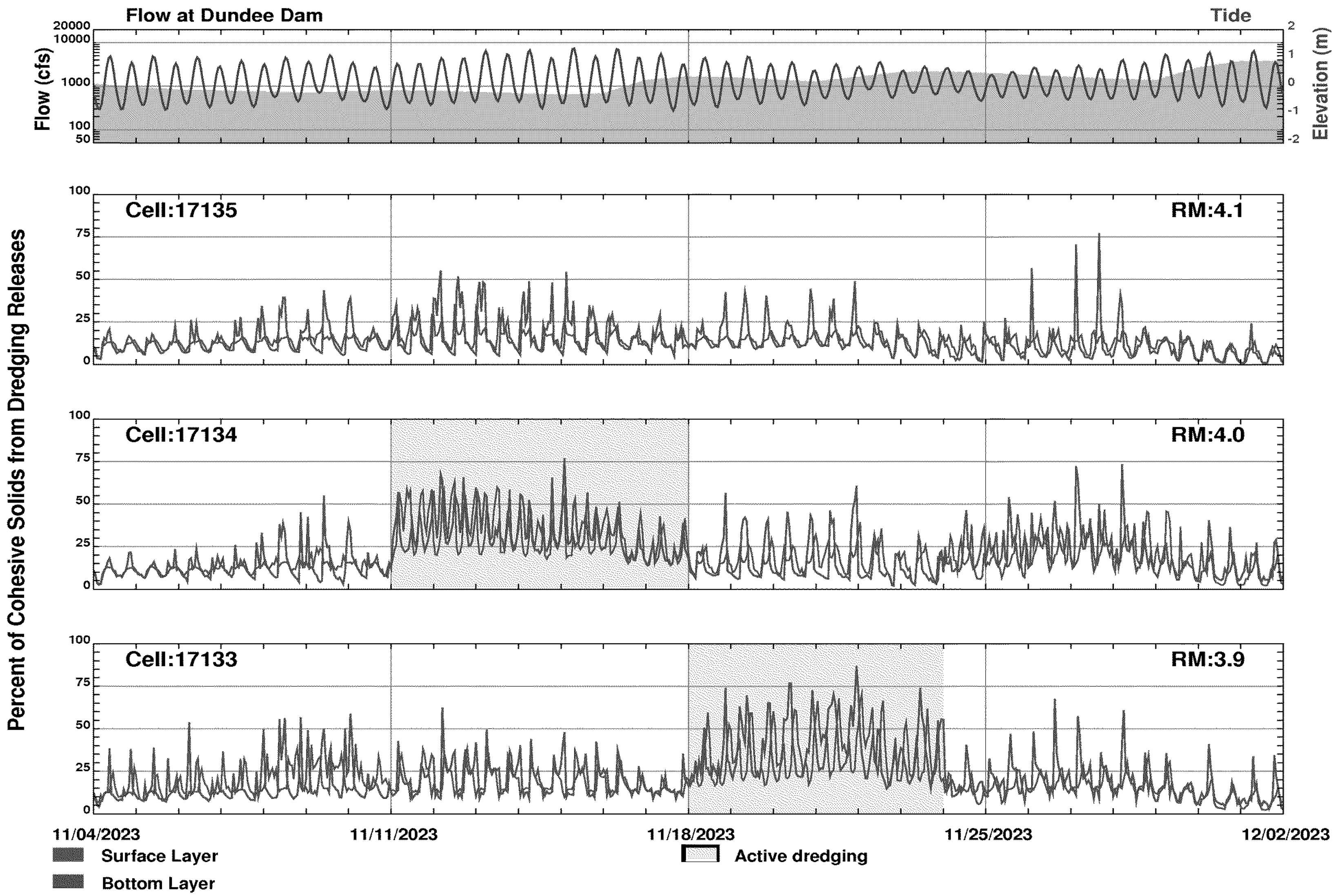


Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 4.0 bottom layer (Assumption: resuspension loss is 3% of dredged mass)

Lower 8.3 Miles of the Lower Passaic River

Figure 12

2016

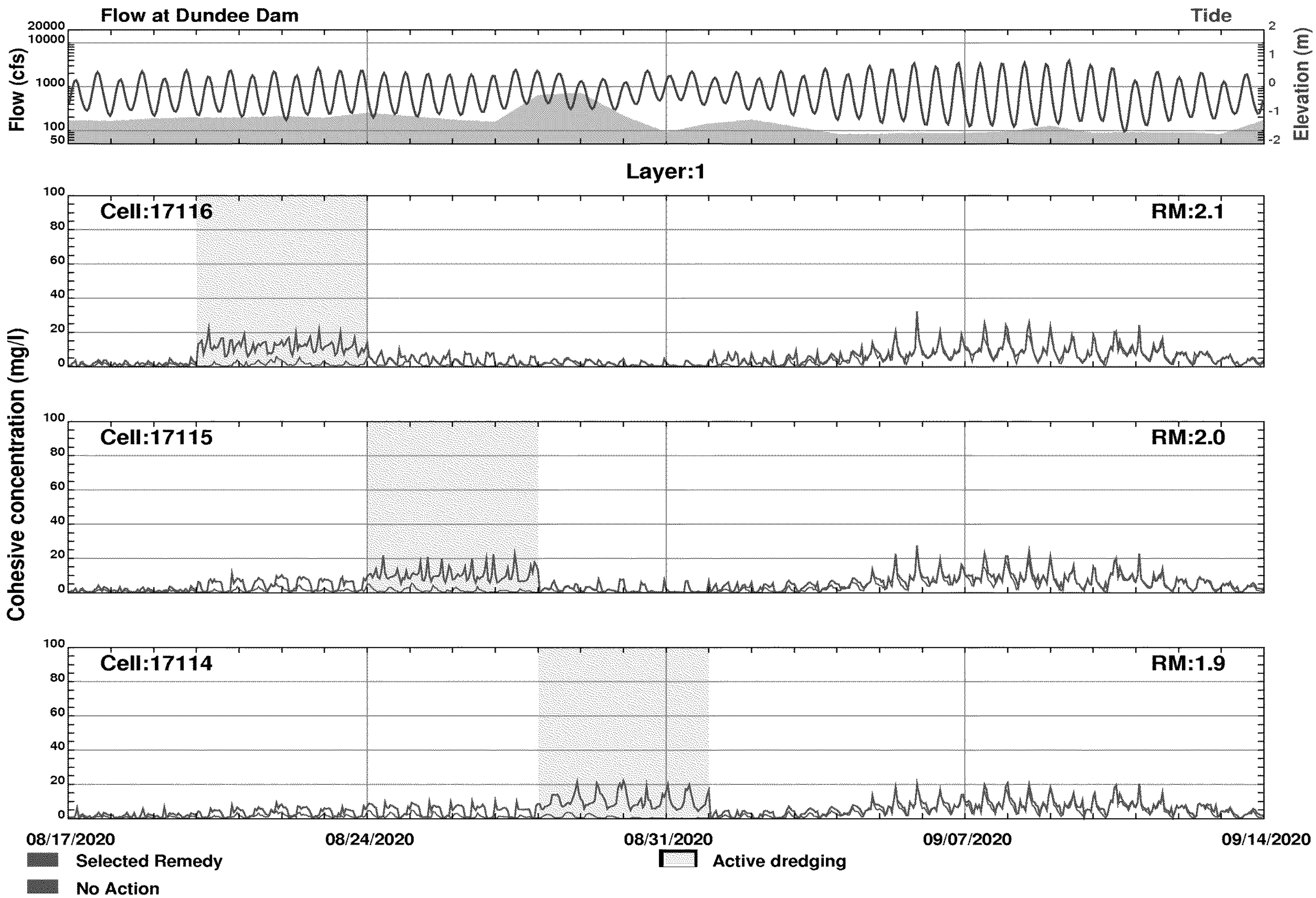


Percentage of suspended cohesive solids from dredging releases near RM 4.0
(Assumption: resuspension loss is 3% of dredged mass)

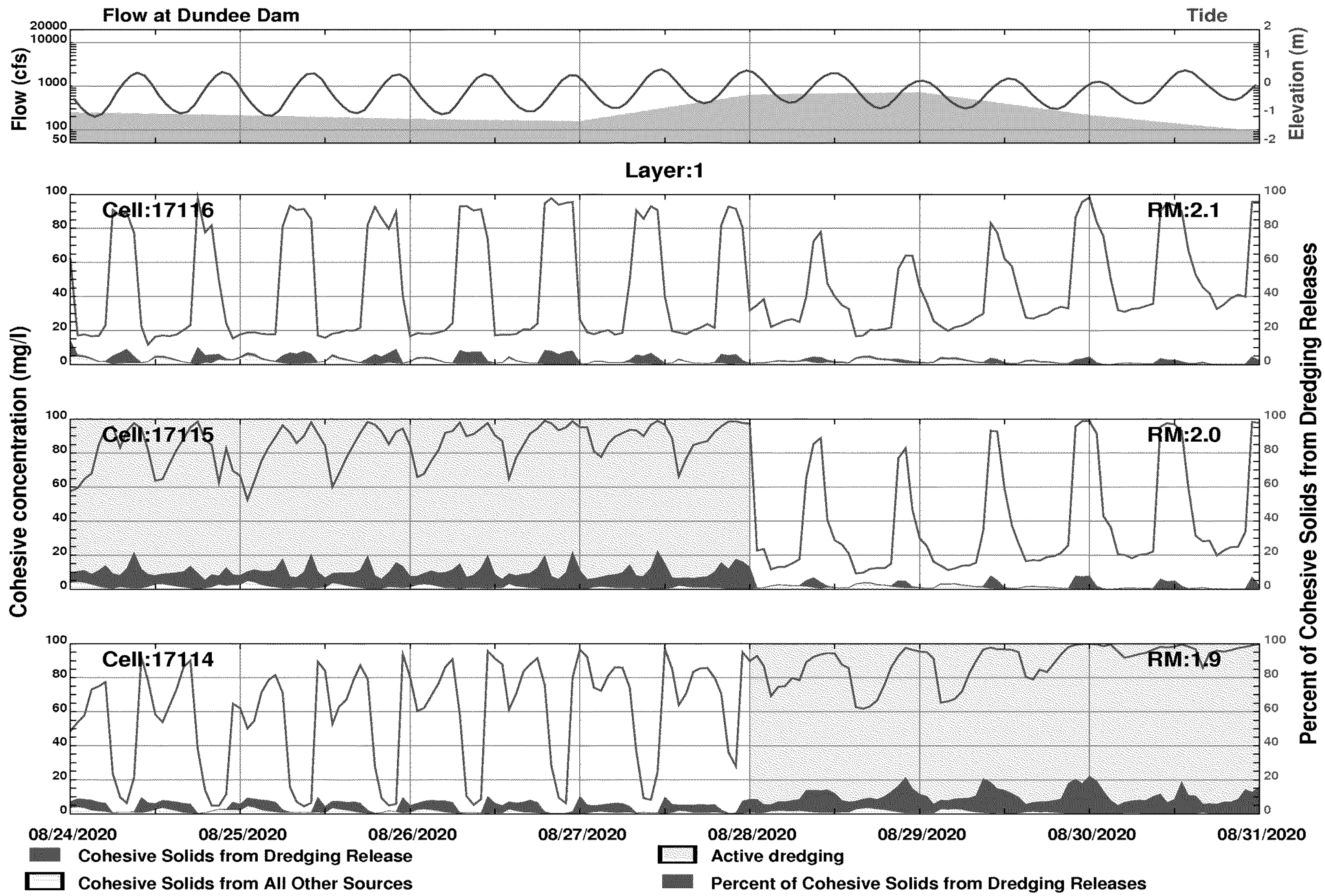
Lower 8.3 Miles of the Lower Passaic River

Figure 13

2016



Comparison of suspended cohesive solids concentrations from Selected Remedy and No Action near RM 2.0 surface layer (Assumption: resuspension loss is 3%of dredged mass)	Figure 14
Lower 8.3 Miles of the Lower Passaic River	2016

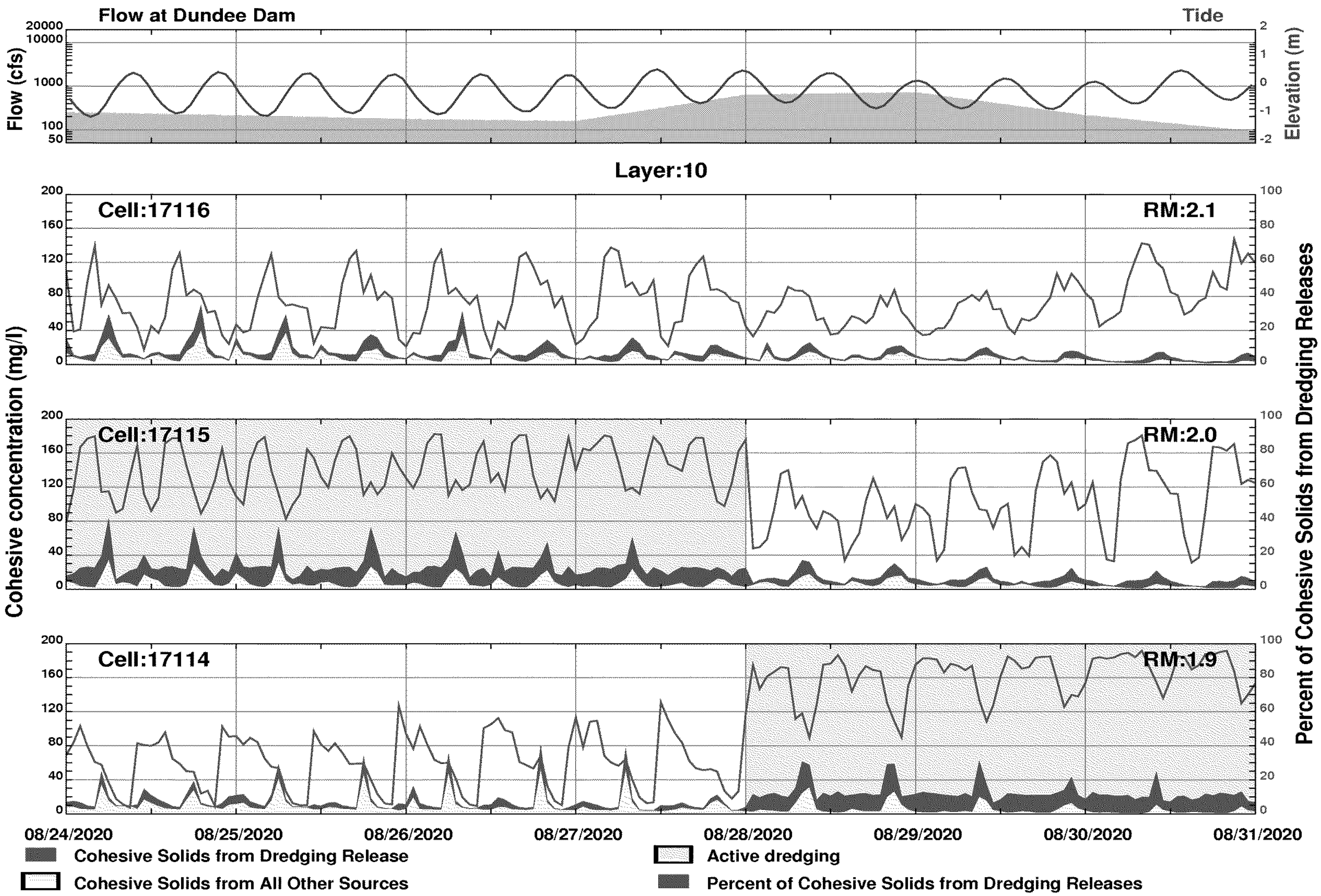


Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 2.0 surface layer (Assumption: resuspension loss is 3% of dredged mass)

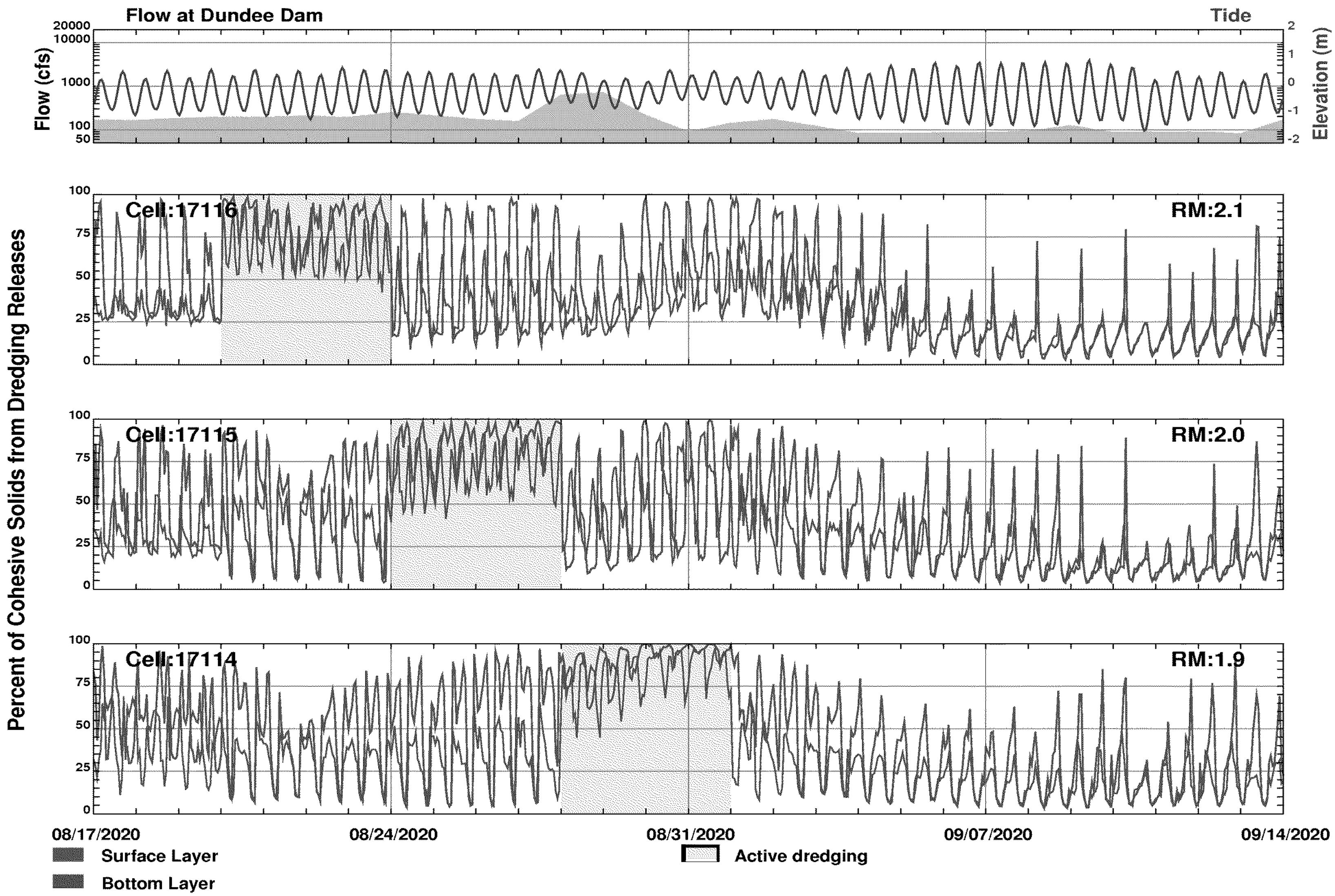
Lower 8.3 Miles of the Lower Passaic River

Figure 15

2016



Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 2.0 bottom layer (Assumption: resuspension loss is 3% of dredged mass)	Figure 16
Lower 8.3 Miles of the Lower Passaic River	2016

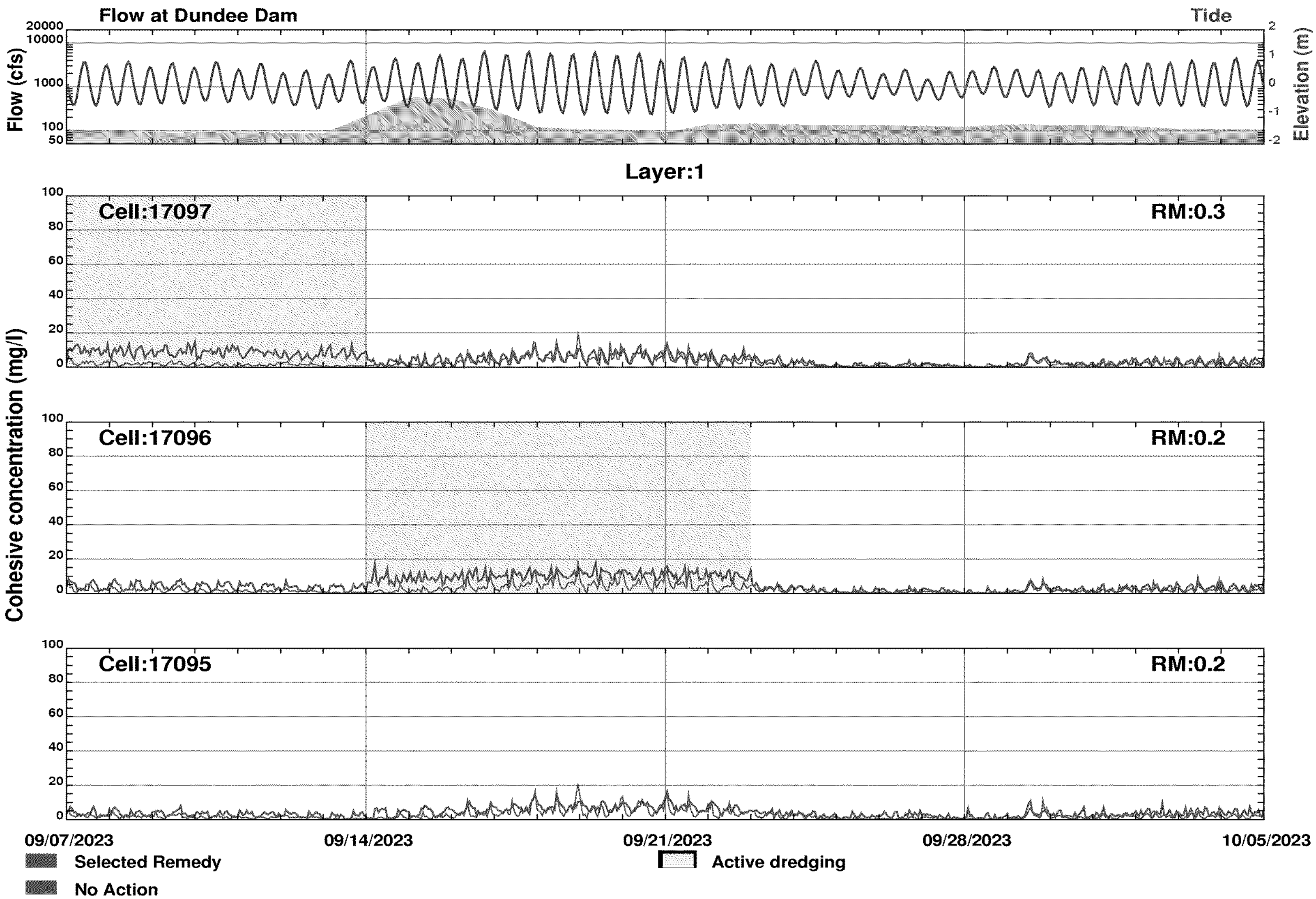


Percentage of suspended cohesive solids from dredging releases near RM 2.0
(Assumption: resuspension loss is 3% of dredged mass)

Lower 8.3 Miles of the Lower Passaic River

Figure 17

2016

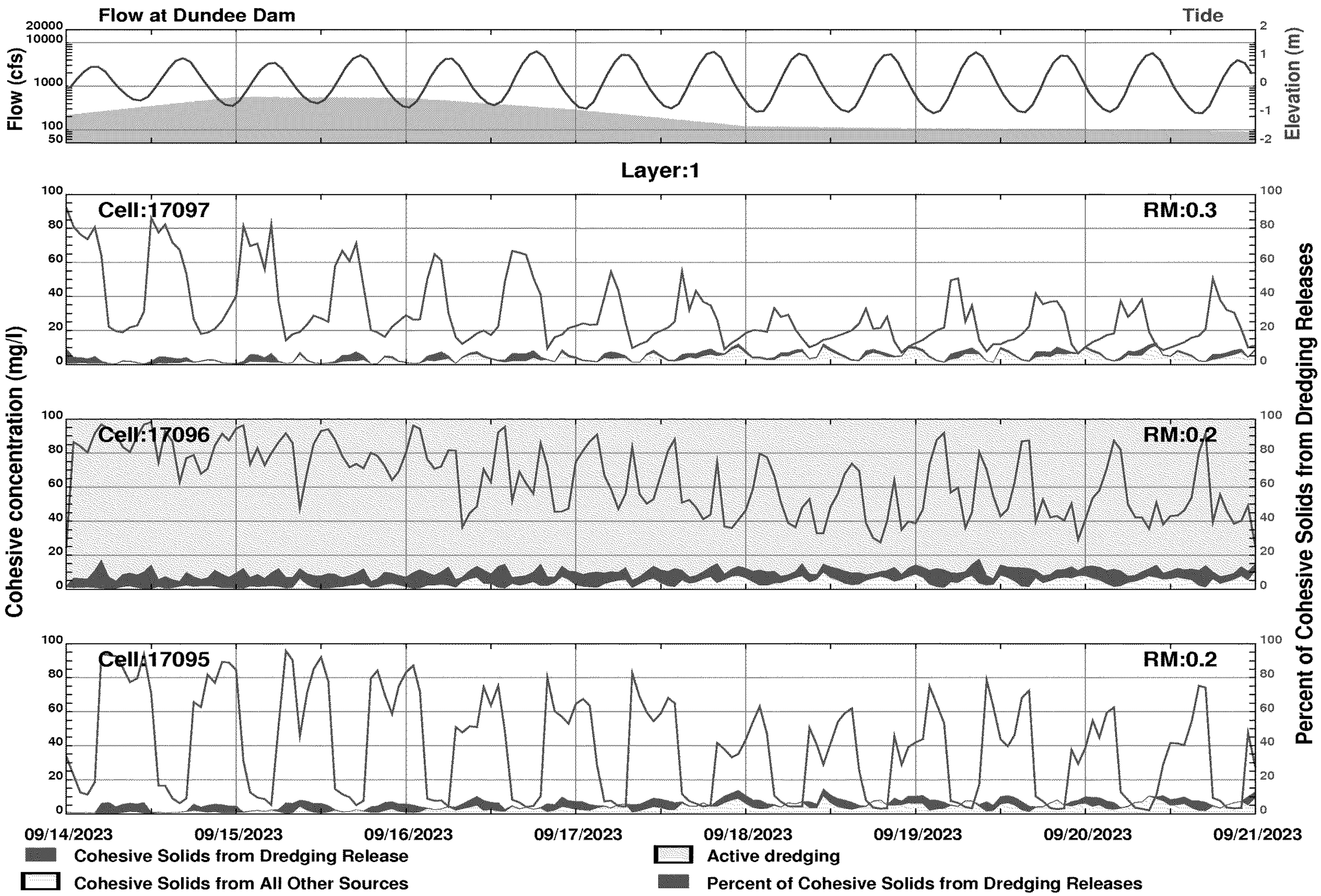


Comparison of suspended cohesive solids concentrations from Selected Remedy and No Action near RM 0.2 surface layer (Assumption: resuspension loss is 3%of dredged mass)

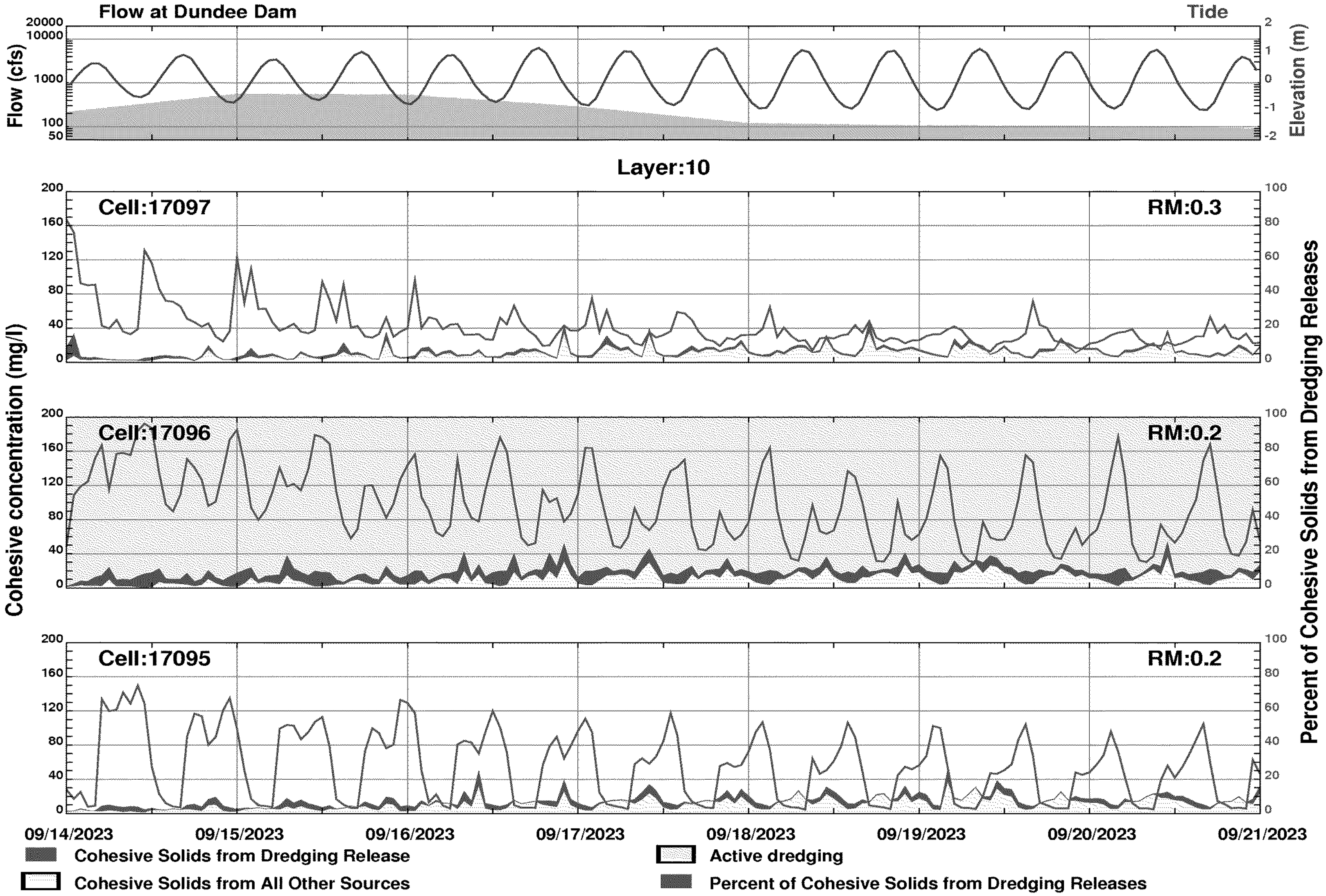
Lower 8.3 Miles of the Lower Passaic River

Figure 18

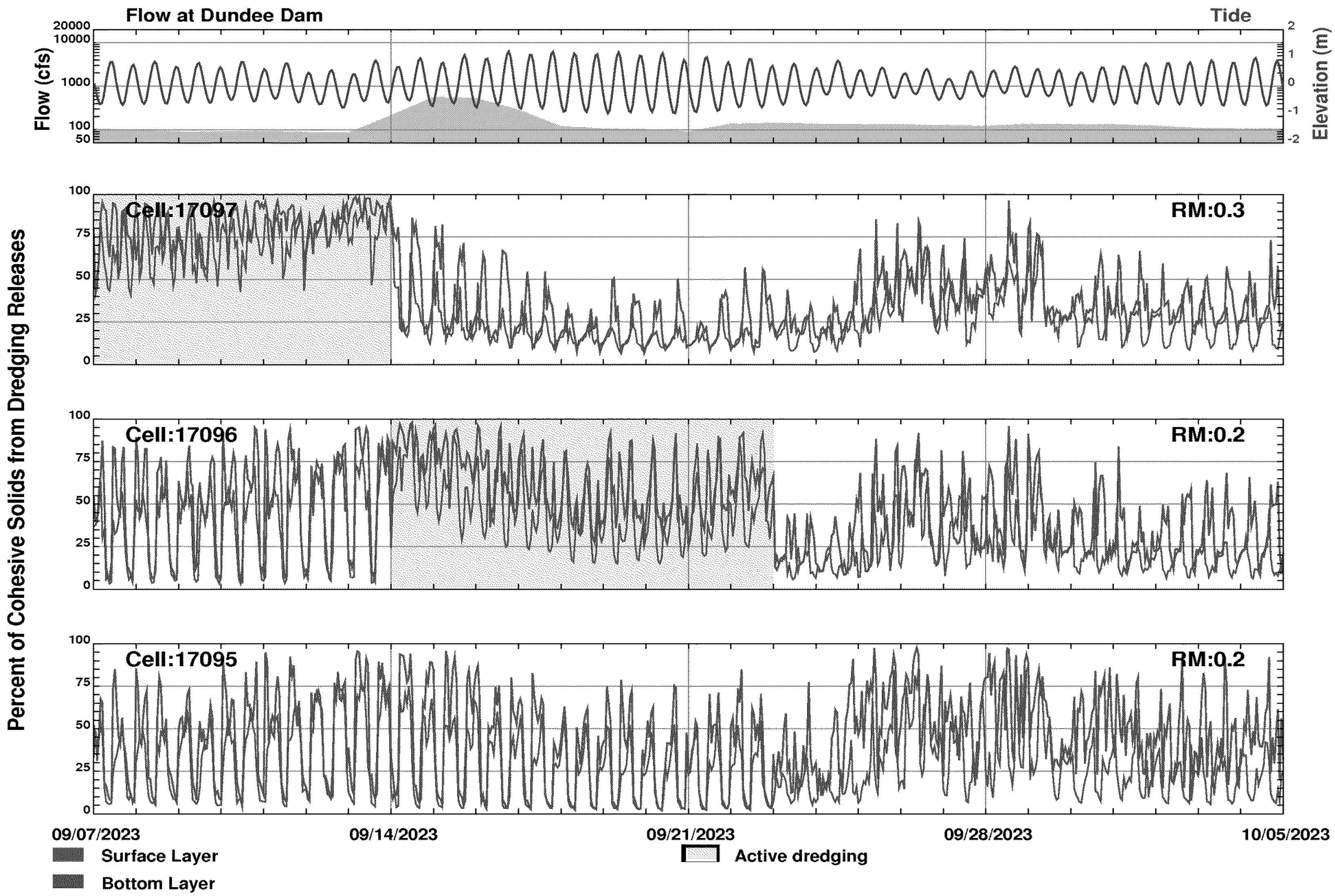
2016



Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 0.2 surface layer (Assumption: resuspension loss is 3% of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 19 2016



Suspended cohesive solid concentrations from dredging releases and other sources, and percentage of solids from dredging releases near RM 0.2 bottom layer (Assumption: resuspension loss is 3% of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 20 2016



Percentage of suspended cohesive solids from dredging releases near RM 0.2 (Assumption: resuspension loss is 3% of dredged mass) *Lower 8.3 Miles of the Lower Passaic River*	Figure 21 2016